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Nider

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[54] **PROCESS FOR CARBONIZING AN AGRICULTURAL PRODUCT**

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[58] **Field of Search** 110/346, 243, 244, 246, 110/229; 432/118; 34/108, 130, 131, 132, 10

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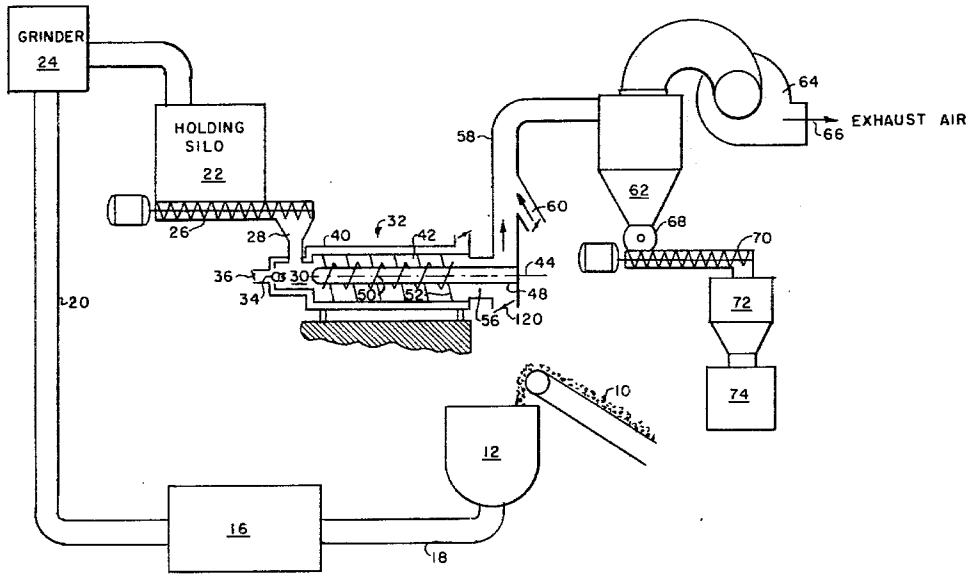
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[57] **ABSTRACT**

A process for treating an agricultural product having a high silica content utilizes the steps of supplying hot gases and combustion air to a combustion zone, dispersing the agricultural product in the hot gases and combustion air for controlled burning thereof and then arresting the combustion process after evolution of the volatile constituents and organic matter and prior to oxidation of the carbon constituents remaining in the agricultural product.

9 Claims, 3 Drawing Figures



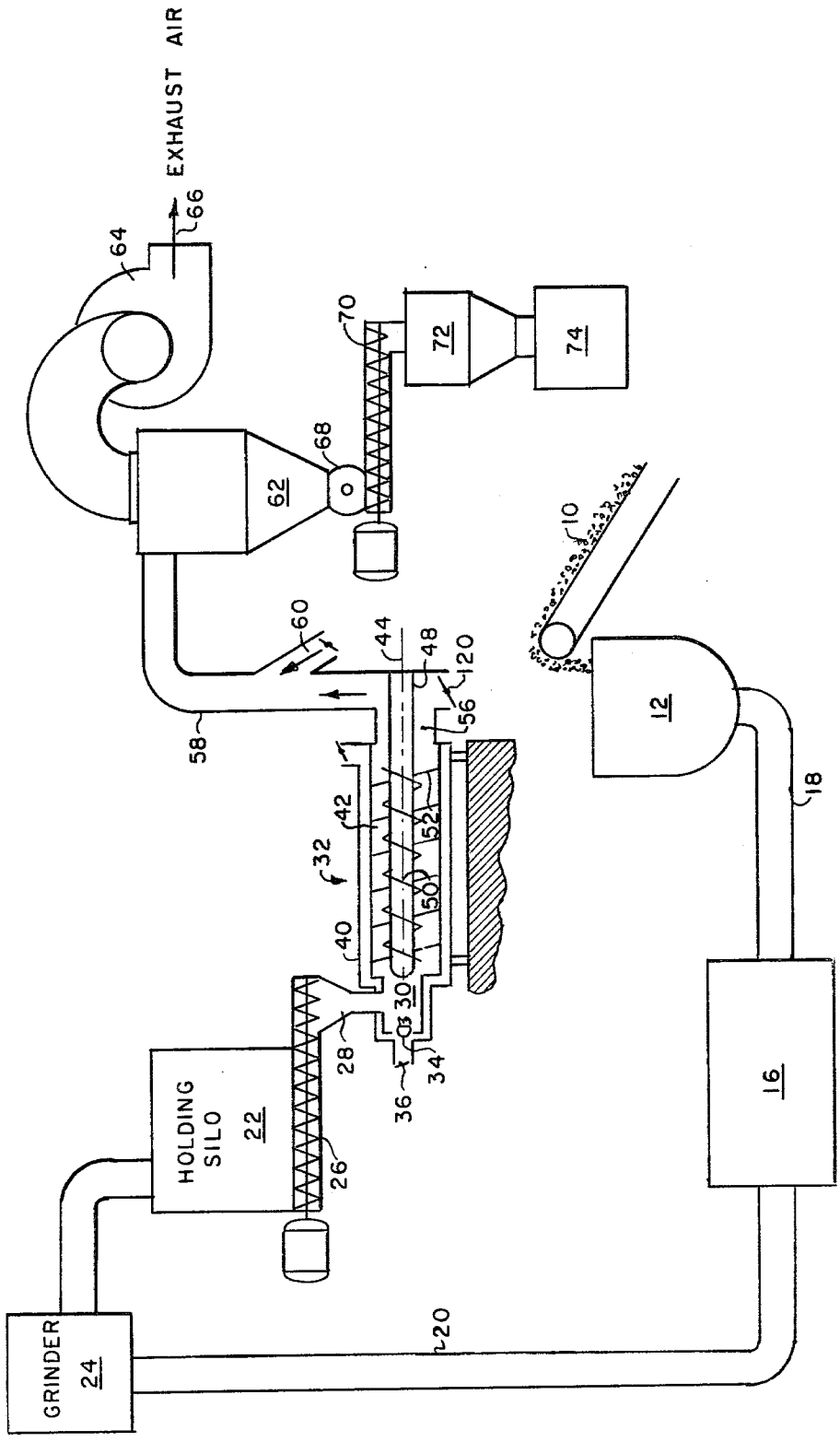

EXHAUST AIR
66
64
70
72
74
62
68
10
60
44
48
120
56
58
12
18
42
32
52
50
40
30
28
34
36
HOLDING SILO 22
26
16
GRINDER 24
20

FIG. 1

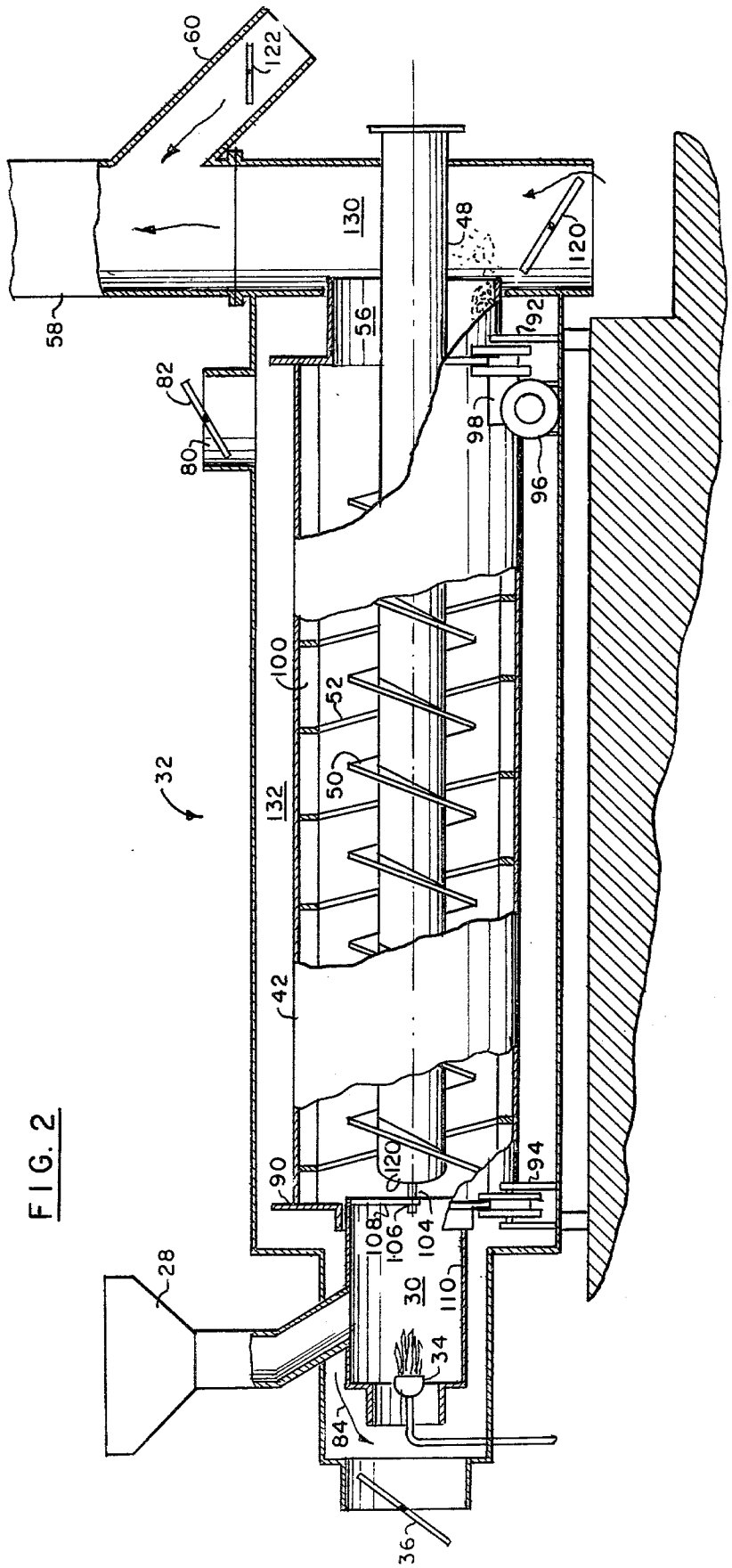
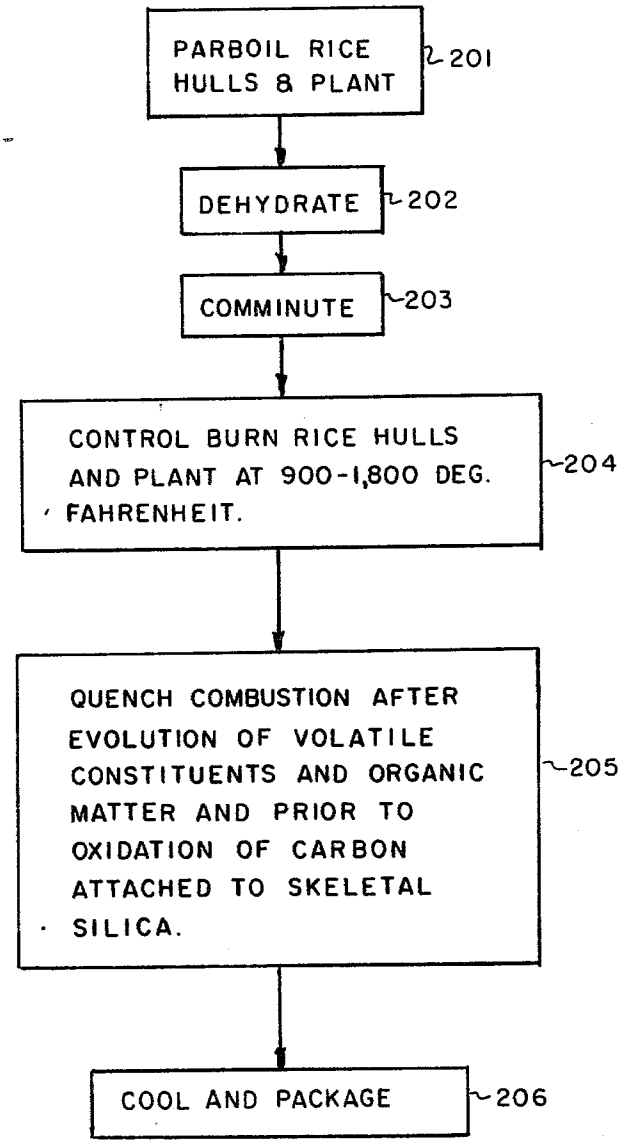

60
122
130
48
120
58
56
92
82
80
98
96
100
52
32
50
132
42
90
120
94
108
106
104
28
30
110
34
84
36

FIG. 2

FIG. 3


PARBOIL RICE HULLS & PLANT
201
DEHYDRATE
202
COMMINUTE
203
CONTROL BURN RICE HULLS AND PLANT AT 900-1,800 DEG. FAHRENHEIT.
204
QUENCH COMBUSTION AFTER EVOLUTION OF VOLATILE CONSTITUENTS AND ORGANIC MATTER AND PRIOR TO OXIDATION OF CARBON ATTACHED TO SKELETAL SILICA.
205
COOL AND PACKAGE
206

PROCESS FOR CARBONIZING AN AGRICULTURAL PRODUCT

BACKGROUND OF THE PRIOR ART

This invention relates generally to apparatus and processes for treating an agricultural product and in particular to an apparatus and process for carbonizing an agricultural product having a high silica content.

Of the few agricultural products having a high silica content, rice hulls and the rice plant itselt represent a major disposal problem where uncontrolled burning of agricultural waste is prohibited by various environmental laws.

By controlling the burning of the rice hull and the rice plant to remove volatile constituents and organic matter leaving only the carbon constituents attached to the skeletal silica in the material, a valuable commercial product is obtained which can be used in other chemical processes.

In prior art processes and apparatus, burning temperatures were controlled to be below the temperature which would cause the skeletal structure of the plant material to fuse but high enough to cause the volatile constituents and organic matter to be removed. The process was performed in a combustion zone in which hot gases and combustion air were swirled about a vertical axis while the hull material was continuously provided to the combustion zone. In the prior art process, the processed hulls would fall, pulled by gravity, through the combustion zone and be removed at the lower portion of the zone. In such an apparatus, the particles would not necessarily fall through the combustion zone at the same velocity because of the variation in particle weight and aerodynamic shape or each particle. Some particles would remain in the combustion zone too long causing the carbon constituent to become oxidized while the heavier and more streamlined particles would pass too quickly through the zone and not be completely processed.

In addition, some of the incompletely processed particles would continue to burn after leaving the combustion zone causing uncontrolled oxidation of the carbon contained in the particles resulting in an inferior product.

Such a process would result in a non-uniform product, especially where the rice plant parts are processed along with the rice hulls.

SUMMARY OF THE INVENTION

A process for treating an agricultural product comprises the steps of supplying the product to a combustion zone along with hot gases and combustion air, then dispersing the product in the hot gases for controlled burning at a temperature below the fusion point of the skeletal silica but sufficient to cause evolution of the volatile constituents and organic matter, then arresting the burning or combustion process after evolution of substantially all of the volatile constituents and organic matter but prior to oxidation of the carbon constituents remaining in the product. In addition, the agricultural product can be parboiled, then dehydrated prior to entering the combustion zone. The agricultural product can also be comminuted prior to being introduced into the combustion zone.

It is, therefore, an object of the present invention to provide an apparatus and process for controlled burning of an agricultural product.

It is a further object of the present invention to provide an apparatus for controlled burning of an agricultural product having a high silica content utilizing a rotatable cylindrical vessel having a horizontal axis of rotation.

It is another object of the present invention to provide an apparatus for controlled burning of an agricultural product leaving carbon attached to the skeletal silica in which hot gases are swirled about inside a rotatable cylindrical vessel utilizing a vortex creating barrier and non-rotatable central support member.

It is yet another object of the present invention to provide an apparatus for controlled burning of an agricultural product in which the combustion is quenched after evolution of the volatile constituents and organic matter but prior to oxidation of the remaining carbon.

It is a further object of the present invention to provide an apparatus for controlled burning of an agricultural product utilizing a combustion zone in which the hot gases are turbulated in a vortex utilizing helical barriers about the inside of the rotatable cylinder.

It is a further object of the present invention to provide a process for treating an agricultural product utilizing hot gases and combustion air for controlled burning of the product and then arresting the burning process after evolution of all the volatile constituents and organic matter but prior to oxidation of the carbon constituents.

It is a further object of the present invention to provide a process for treating an agricultural product in which the agricultural product may be parboiled and then dehydrated prior to its control burning to remove the volatile constituents and organic matter but leave the remaining carbon constituents and skeletal silica.

It is yet another object of the present invention to provide a process for treating an agricultural product in which the product is comminuted prior to being introduced into the combustion zone.

It is yet another object of the present invention to provide a process for treating an agricultural product in which the product is burned under controlled temperature and time conditions at a temperature below the fusion point of the skeletal silica but sufficiently high enough to cause evolution of the volatile constituents and organic matter.

It is yet another object of the present invention to provide a process for treating an agricultural product in which the combustion process is arrested by cold air.

It is a further object of the present invention to provide a process for treating an agricultural product in which the combustion process is arrested by an inert gas.

It is a further object of the present invention to provide a process for treating an agricultural product in which the combustion process is arrested or quenched by water vapor.

These and other object of the present invention will be manifest upon study of the following detailed description when taken together with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram showing the equipment and steps used in processing the agricultural product of the present invention.

FIG. 2 is a partial cross-sectional elevational view of the apparatus for controlled burning of the agricultural product of the present invention.

FIG. 3 is schematic diagram showing the various steps of the process for treating the agricultural product of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The overall process and apparatus for performing the process is best illustrated in FIG. 1 in which the incoming raw agricultural product **10** is conveyed to barboiling vessel **12** by raw material conveyor **14**. In parboiler vessel **12** the raw agricultural product is boiled to soften the product and, for rice hulls, to remove the rice kernel for separation from the hull. In most situations, however, the raw agricultural material may be conveyed directly to holding silo **22** or grinder **24**.

The parboiled product, namely rice hulls and rice plant material, for example, is conveyed from the parboiler vessel **12** to dehydrator **16** through parboiled product conveyor **18**.

The moist product is then dehydrated in dehydrator **16** where it is conveyed by dehydrated products conveyor **20** up to holding silo **22**.

Normally the step of parboiling the incoming agricultural product and then dehydrating it is performed at the rice processors plant and can be conveyed to holding silo **22** either by a conveyor **20** as shown, where the distance is short, or by truck where the plant for carbonizing the material is some distance away from the rice processing plant. Prior to entering holding silo **22** the dehydrated product can be ground or comminuted to a uniform particle size by grinder **24**.

Screw feed conveyor **26** then transports the dehydrated agricultural product in silo **22** to feed hopper **28** where the material falls into inlet end **30** of furnace **32** which will be described in greater detail below. Burner **34**, located proximate inlet end **30** of furnace **32**, is used to ignite the material falling from hopper **28**, with combustion air entering through combustion air control vent **36** to cause a flow of hot gases and combustion air into inlet end **30** and through furnace **32**.

Furnace **32** comprises, basically, an outer housing or shroud **40** enclosing and spaced apart from rotatable cylindrical vessel **42**. Rotatable cylindrical vessel **42** has a horizontal axis of rotation **44** which is coincident with its cylindrical axis. Furnace **32** further comprises a central support member **48** which is non-rotatable. Helical barrier **50**, attached to central support member **48**, and helical barrier **52**, attached to the inside surface of rotatable cylindrical vessel **42**, are adapted to create a vortex and turbulation of the hot gases and combustion air entering from inlet end **30**.

Within rotatable cylindrical vessel **42** is defined a fireball or combustion zone in which the particles of agricultural material are ignited to above their kindling temperature and where the exothermic reaction takes place. The fire ball or combustion zone is defined by an up-stream flame front and a down-stream tail in which the particles of agricultural material are burned under controlled agricultural product to burn under controlled conditions resulting in the evolution of the volatile constituents and the organic matter in the rice hulls and rice plant material. The burned or processed end product material then passes out of cylindrical vessel **42**, through outlet end **56**, then up through end product air conveyor conduit **58** where the combustion process is then arrested or quenched by burn arrest injector **60**.

The particles then pass into end product particle separator **62** which separates the particles from the exhaust gases. The exhaust gases then pass through blower **64** and out into the atmosphere as shown by arrow **66**.

The flow of end product particles out of particle separator **62** is controlled by rotary valve **68**, which feeds the material into end product conveyor **70** where they are transferred to end product storage bin **72** for later packaging or bagging by end product bagger **74**.

The key to the operation of the process of the present invention and its ability to handle high volumes of agricultural product is furnace **32** which is illustrated in greater detail in FIG. 2.

With reference to FIG. 2, furnace **32** comprises, basically, outer housing or heat conserving shroud **40** having a shroud air supply inlet **80** at which is located shroud air supply control vane or damper **82**, with the outlet end **84** of shroud **40** located proximate inlet end **30** of furnace **32**.

Within housing **40** and spaced apart therefrom is rotatable cylindrical vessel **42** having trunnions **88** and **90** located proximate each end thereof which rest on drive wheels **92** and **94**, respectively. Drive wheel **92** is driven by motor **96** through gear box **98**.

Along the inside surface of rotatable cylindrical vessel **42** is attached helical barrier **52** whose helical members are separated by a plurality of cleats **100**. Cleats **100** are used to lift and disperse the particulate agricultural material into the hot turbulating gases within cylindrical vessel **42**.

Also disposed within cylindrical vessel **42** is non-rotatable central member **48** whose longitudinal axis is generally coincident with the axis of rotation of cylindrical vessel **42** and whose end **102**, which is located proximate inlet end **30**, includes a shaft **104** which is supported by a bracket **106**. Bracket **106** is supported by spider **108** which is attached to inlet end housing **110**. Inlet end housing **110** does not rotate by projects slightly into rotatable cylindrical vessel **42**.

Attached to the outside surface of central support member **48** is helical barrier **50** which is adapted, in cooperation with helical barrier **52**, to cause a vortex and turbulation of the hot gases and combustion air passing from inlet end **30** through cylindrical vessel **42** and out of outlet end **56**. Barriers **50** and **52** thus insure the uniform burning and processing of the particulate agricultural material within cylindrical vessel **42**.

Burner **34** is provided proximate inlet end **30** to generate the hot gases and flame which causes the particulate agricultural material to be ignited as they enter inlet end **30** from hopper **28**. Combustion air control vane or damper **36** is located upstream from burner **34** to regulate the flow of combustion air for the controlled burning of the particulate agricultural material in cylindrical vessel **42**.

Combustion air moderator valve vane or damper **120** is located proximate outlet end **56** of rotatable cylindrical vessel as a further control of the combustion process. The processed particulate agricultural material is transported by the hot gases through outlet end **56** and through conduit or conveyor **58** where the burning process is immediately quenched through the use of burn arrest injector **60**.

Burn arrest injector **60** comprises a control vane **122** which regulates the flow of cold air, water vapor or

inert gases into conduit **58** to either cool the material to below its kindling point or starve the area around the particle of oxygen.

With respect to FIG. **3** there is illustrated the steps of the process for treating the agricultural product of the present invention which comprises, basically, the optional step **201** of parboiling the rice hulls and plant material, then the step **202** of dehydrating the parboiled material followed by step **203** of comminuting the dehydrated or raw material which is then, at step **204**, placed in the combustion zone on furnace **32**. While in the combustion zone, the volatile constituents and organic matter are volatilized by controlled burning at a temperature between 900 and 1,800 degree Fahrenheit, after which, at step **205**, the combustion process is quenched or arrested after all of the volatile constituents and organic matter are removed but prior to oxidation of the carbon remaining on the skeletal silica of the agricultural product. At step **206**, the particulate end product is then cooled and packaged or bagged as desired.

It is important that the controlled burn be maintained at a temperature between 900 and 1,800 degrees Fahrenheit to avoid fusing or melting the skeletal silica structure of the rice hulls and rice plant materials.

The combustion process can be quenched in either of two ways, by either cooling the particulate end product to below its ignition temperature or by starving the oxygen around the particulate end product to prevent further oxidation of the carbon remaining attached to the skeletal silica. The quenching step is necessary to achieve a uniform high quality product which is high in carbon and low in volatile constituents and organic matter.

Quenching can be accomplished through the use of cold air, water vapor, or through the use of an inert gas such as carbon dioxide or nitrogen.

Central support member **48** can also function as a heat exchanger whereby the excess heat generated by the exothermic reaction of the burning of the rice hulls and rice plant or other agricultural material can be converted into steam which can be used in other steps of the process or to provide electrical energy to assist in running the plant.

To operate furnace **32** of the present invention, rice hulls and rice plant materials are delivered to inlet end **30** through hopper **28** and ignited by burner **34**, which combustion is supported by combustion air entering through combustion air control **36**. As the hot gases pass into rotatable cylindrical vessel **42**, they are caused to turbulate in a vortex manner around central support member **48** by helical barrier **50** and **52**. Such vortex action and turbulating of the hot gases permits all the particulate agricultural material to be exposed and the combustion thereof supported in the form of a fireball having a flame front and a combusting tail. In addition, as rotatable cylindrical vessel **42** is rotated by electric motor **96**, the heavier particulate material is raised to a higher level by cleats **100** and then allowed to spill down through the hot turbulating gases and combustion air to be transported thereby down the length of cylindrical vessel **42** toward outlet end **56** in stages. Helical barrier **52**, which is attached to the inside surface of rotatable cylindrical vessel **42**, further assists in transporting the heavier particulate material toward outlet end **56** acting somewhat in the manner of a screw conveyor. After the particulate material reaches outlet end **56** it spills into end plenum **130** where it is carried up into air end product conveyor by the rush of air coming in from combustion air moderator **120**. The total volume of air flowing up through conduit **58** is controlled by blower **64** (FIG. **1**).

The flow of combustion air into rotatable cylindrical vessel **42** is controlled both by shroud air supply control **82** and combustion air control **36** and moderator valve **120**. The flow of air into space **132** between housing **40** and rotatable cylindrical vessel **42** will determine the cooling effect on cylindrical vessel **42** and the rise in temperature of air passing through space **132**. By adjusting shroud air supply control **82**, combustion air control **36**, and the air flow through moderator air valve or damper **120**, the combustion rate of the particles within the combustion zone in cylindrical vessel **42** and the temperature surrounding cylindrical vessel **42** can be controlled.

In adjusting the air flow through furnace **32**, it is important that the flame front of the fireball be kept within cylindrical vessel **42**. Preferably the flame front should be maintained more than half way down vessel **42** in the direction of outlet end **56**. The end of the combustion tail of the fireball should terminate proximate outlet end **57** although it could extend into plenum **130**. In some cases the tail of the fireball could extend into conduit **58**, however, this would tend to cause deterioration of conduit **58** and increase the maintenance costs of the apparatus.

If the flame front is maintained too close to inlet end **30**, it has been found that excessive smoke will be generated.

After the fireball is created by the use of igniter **34**, the flame level of ignited **34** can be reduced to a point where it will produce only enough hot gases to maintain ignition of the fireball.

The key factor is to adjust the flow of combustion air through cylindrical vessel **42** such that its velocity will maintain the flame front of the fireball at a fixed position within cylindrical vessel **42**. At the same time, the amount of feed material entering inlet end **30** from hopper **28** is adjusted to maintain the proper size of the fireball and its tail length without choking vessel **42** with raw material, depending upon the volume flow of combustion air.

The major adjustment of air flow through cylindrical vessel **42** is achieved through the use of moderator valve **120**. An increase flow of air through moderator valve **120** will tend to reduce the flow of air through cylindrical vessel **42**. Conversely, a decrease in the flow of air through moderator valve **120** will increase the flow of air through cylindrical vessel **42**. The total volume of air passing through conduit **58** is, of course, controlled by the velocity of blower **64**.

It also can be seen that an increase in quench air through burn arrestor **60** will also decrease the flow of air through cylindrical vessel **42**.

Of course, by opening shroud air vent **82** and combustion air vent **36**, combustion air through cylindrical vessel **42** can be increased.

It has been found that once the particles that have come through the fireball are reduced in temperature to below 1000 degrees Fahrenheit, the combustion process is quenched. This can be done readily using either cold air or air in which water is aspirated. Both the water vapor and the reduction in air temperature due to evaporative cooling by the water vapor quickly quenches the combustion process of the particles. Also an inert gas such as carbon dioxide or nitrogen can be used.

Steam can also be used to quench the combustion process.

Temperature measurements taken within the fireball indicate a combustion temperature of between 1400 to 1800 degrees Fahrenheit. Observations indicate that the smaller particles of agricultural material tend to pass through the fireball faster than the larger particles. Since the smaller particles have less material to volatilize, they are prevented from being overprocessed, that is, they are quenched before the remaining carbon is oxidixed by the excess combustion air. The larger particles, because they pass through the fireball at a slower rate, are prevented from being underprocessed, that is, left with unvolatilized material and organic matter on the skeletal silica.

By adjusting the amount of combustion air relative to its velocity through cylindrical vessel **42**, along with the material feed volume rate, the time of passage through the fireball can be controlled whereby the processed or burned end product will be quenched just after all of the volatile and organic constituents have been removed but prior to oxidation of the remaining carbon attached to the skeletal silica. Sampling the end product will determine the optimum air and material feed rates.

Thus is described a process and apparatus for controlled carbonizing of an agricultural product.

I claim:

1. In a process for treating an agricultural product having a high silica content comprising the steps of

supplying said agricultural product to a combustion zone,

supplying hot gasses and combustion air to said combustion zone,

dispersing said agricultural product in said hot gases and combustion air for controlled burning of said agricultural product at a temperature below that which causes fusion of said skeletal silica in said agricultural product but sufficient to cause evolution and combustion of volatile constituents and organic matter in said agricultural product,

the improvement comprising

arresting the combustion process of said agricultural product after evolution of said volatile constituents and organic matter and prior to oxidation of carbon constituents remaining in said agricultural product.

2. The process as claimed in claim **1** further comprising the steps of

comminuting said agricultural product to a uniform particle size prior to supplying said agricultural product to said combustion zone.

3. The process as claimed in claim **1** further comprising the steps of

parboiling said agricultural product, and

dehydrating said parboiled agricultural product prior to supplying said agricultural product to said combustion zone.

4. The process as claimed in claim **3** further comprising the steps of

comminuting said agricultural product to a uniform particle size after dehydrating said parboiled agricultural product.

5. The process as claimed in claim **1** wherein the step of arresting the combustion process comprises

chilling said agricultural product to below its ignition temperature by exposing said agricultural product to cold air.

6. The process as claimed in claim **1** wherein the step of arresting the combustion process comprises

exposing said agricultural product to an inert gas.

7. A process for treating an agricultural product having a high silica content comprising the steps of

supplying said agricultural product to a combustion zone,

supplying hot gases and combustion air to said combustion zone, said combustion zone being characterized by said hot gases being swirled about a generally horizontal axis,

dispersing said agricultural product in said hot gases by rotating said agricultural product in a rotatable cylindrical vessel having a horizontal axis of rotation coincident with the cylindrical axis of said rotatable cylindrical vessel for controlled burning of said agricultural product at a temperature below that with causes fusion of skeletal silica but sufficient to cause evolution and combustion of volatile constituents and organic matter in said agricultural product, and

arresting the combustion process of said agricultural product after evolution of said volatile constituents and organic matter and prior to oxidation of carbon constituents remaining in said agricultural product.

8. The process for treating an agricultural product as claimed in claim **7** wherein

said combustion zone is further characterized by hot gases being swirled about a horizontal axis by a first barrier attached to the interior surface of said rotatable cylindrical vessel, said first barrier defining a helix beginning proximate one end of said combustion zone and extending proximate the length of said combustion zone.

9. The process for treating an agricultural product as claimed in claim **7** wherein

said combustion zone is further characterized by hot gases being swirled about a horizontally disposed central member extending proximate the length of said combustion zone by a second barrier attached to said central support member, said barrier defining a helix beginning proximate one end of said central support member and extending proximate the other end of said central support member.

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